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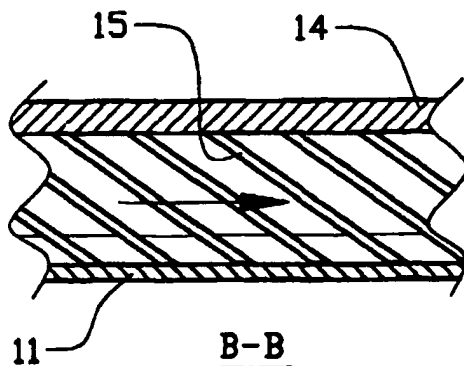
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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: **ROCKET ENGINE MEMBER AND A METHOD FOR MANUFACTURING A ROCKET ENGINE MEMBER**



(57) Abstract: The invention relates to a liquid fuel rocket engine member. The member has a load bearing wall structure (11, 14) comprising a plurality of cooling channels (11) for handling a coolant flow. Each cooling channel (11) is provided with a flow guiding surface (15) extending at an angle to the cooling channel axis, for providing the axial coolant flow with an added radial directional flow component.

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Title:

**Rocket engine member and a method for manufacturing a rocket engine member**

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#### TECHNICAL FIELD

The present invention relates to a liquid fuel rocket engine member having a load bearing wall structure comprising a plurality of cooling channels for handling a coolant flow. The invention also relates to a method for manufacturing the rocket engine member.

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#### BACKGROUND OF THE INVENTION

During operation, the heat load is very intensive inside a rocket combustion chamber. The walls of the combustion chamber must be cooled efficiently not to melt or in other ways destroy the structure. The most common way to cool the chamber wall is cooling by convection. The cool fuel and even the oxidizer is used for cooling.

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The service life of the chambers is often a problem. Much care must be taken to ensure proper function. Inspection and repair in development and in use of the engines is costly. The service life is very much depending on the temperature level of the wall structure closest to the flame. The temperature gradient over the cooling channels generates thermal stress. The elevated temperatures degrade the material properties. Therefore, the service life is very strongly influenced by the temperature. Reduction of the temperature by 100 °K leads to about three times increase in service life and 10 times increase in creep life.

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The intense heat load leads to stratification of the coolant. The coolant closest to the hot wall is heated which results in a temperature increase. The viscosity of the coolant is lowered leading to increased flow speed closest to the heated wall. Thus, the coolant is stratified with sharp temperature gradients. A large share of the coolant is only heated to a low temperature level, reducing the efficiency of the cooling system. The temperature difference in the coolant may be in the order of 600-700 °K. At the outer side of the cooling channel, near the outlet end, the coolant may still have the inlet temperature of 60 °K.

It has been proposed to enlarge the cooling surface of the cooling wall, for example by having longitudinal fins along the inside the channels. However, the fins need to have some height to penetrate the thermal boundary layer. The coolant flow speed will be slowed down in the gap between the fins in case they are made high and close together. Therefore, the increase in heat transfer is limited with this measure. Also, the bottom of the fins needs to be sharp to give room to a large number of fins. The sharp bottom is perpendicular to the first principle stress. The channel bottom represents an important stress concentration. The fins are delicate to manufacture. The width of the channels at the throat area is in the order of 1.0 mm, which means that the maximum width of one of three fins is 0.3 mm and the tip of the fin becomes infinitely thin.

30

Also, it has been proposed to make heat transfer more effective by increasing the channel wall surface roughness to generate turbulence in the coolant flow. The

surface roughness increases the vortexes at the wall, but the effect is small with a very low viscosity fluent as hydrogen.

5 JP 60048127 teaches the use of a twisted steel band inside a horizontal cooling channel to force a secondary flow to avoid stratification. This method is proposed for application in nuclear plants at horizontal pipes in reactors, intermediate pump, heat exchanger and inlet  
10 nozzle of steam generator. The steel band may lead to hot spots at the hot side and overheating of the material due to a reduced flow of coolant in the channel.

#### SUMMARY OF THE INVENTION

15 An object of the present invention is therefore to provide a rocket engine member with a reduced stratification of the coolant inside the cooling channels.

This is achieved by means of the member according to the  
20 invention, which is characterized in that each cooling channel is provided with a flow guiding surface extending at an angle to the cooling channel axis, for providing the axial coolant flow with an added radial directional flow component. The flow guiding surface forces the coolant to  
25 rotate as it flows through the channel, so that stratification is avoided.

The method according to the invention is characterized by the steps of shaping a sheet metal surface to provide a  
30 flow guiding surface, folding the sheet metal into cooling channels, and attaching the cooling channels to the wall structure.

Advantageous embodiments of the invention can be derived from the subsequent contingent claims.

#### BRIEF DESCRIPTION OF THE DRAWINGS

5 The invention will be further described in the following, in a non-limiting way with reference to the accompanying drawings in which:

FIG 1 is a schematic perspective, partly cut view of a rocket combustion chamber according to the invention,

FIG 2 shows in a larger scale a longitudinal section through a cooling channel of the combustion chamber shown in Fig. 1, according to a first embodiment of the invention,

FIG 3 is a cross section of the cooling channel according to Fig. 1 and 2,

FIG 4 is a section along the line A-A in Fig. 3,

FIG 5 is a section corresponding to Fig. 2, according to a second embodiment of the invention, and

FIG 6 is a cross section of the cooling channel according to Fig. 5.

FIG 7 is a section corresponding to Fig.2, according to a third embodiment of the invention.

FIG 8 is a cross section of the cooling channel according to Fig.7.

FIG 9 and FIG 10 illustrate an example of the manufacturing of each of the channel structures, wherein Fig.9 shows a machined, unfolded sheet and Fig. 10 shows the sheet of Fig.9 in a folded state, forming a part of a cooling channel.

## DETAILED DESCRIPTION OF THE INVENTION

Figure 1 shows a diagrammatic and somewhat simplified side view of a rocket engine combustion chamber 10 that has been produced in accordance with the present invention.

5 The combustion chamber is intended for use in rocket engines of the type using liquid fuel, for example liquid hydrogen. The working of such a rocket engine is previously known per se and is therefore not described in detail here. The combustion chamber 10 is cooled with the  
10 aid of a cooling medium that is preferably also used as fuel in the particular rocket engine. The invention is however not limited to combustion chambers of this type.

The combustion chamber 10 is manufactured with an outer  
15 shape that forms a body of revolution having an axis of revolution and a cross section that varies in diameter along said axis.

The combustion chamber wall is a structure comprising a  
20 plurality of mutually adjacent cooling channels 11 extending substantially in parallel to the longitudinal axis of the combustion chamber 10 from the inlet end manifold 12 to its outlet end manifold 13. The outside of the structure includes a one piece pressure jacket 14. The  
25 U-formed cooling channels 11 are curved in the longitudinal direction to conform to the jacket contour and they are axially oriented along the wall, in this position, they are jointed to the metal jacket wall by brazing.

30 In the embodiment according to figures 2-4, each cooling channel 11 has an internal flow guiding surface comprising a plurality of protruding ribs 15 extending at an angle to

the axis of the cooling channel. The angle of the ribs will force the coolant to rotate inside the channel as the coolant flows along the channel. In this way unheated coolant will be transported from the outside of the channel to the inside and heated coolant will be transported from the inside of the channel to the outside.

Fig. 3 shows a cross section of one of the channels according to Fig. 1. Fig. 2 shows a longitudinal section (a cut side view) of the channel along the line B-B in Fig. 3 and Fig. 4 shows a longitudinal section (a cut view from above) of the channel along the line A-A in Fig. 3.

The flow guiding surface extends at an angle to the cooling channel axis, said angle differs from  $0^\circ$  and  $90^\circ$  in relation to the cooling channel axis. Said angle is preferably between  $1^\circ$  and  $50^\circ$ , especially between  $5^\circ$  and  $30^\circ$  and particularly between  $10^\circ$  and  $20^\circ$  in relation to the cooling channel axis.

It will be possible to reduce the temperature of the combustion chamber by  $100^\circ\text{K}$  by replacing about 15% of the already heated coolant with unheated coolant. The radial flow speed of the coolant should then be around 15% of its axial speed. This represents an angle of 9 degrees from the axial speed vector. This small angle imposes only a small pressure drop to the coolant flow.

The ribbed channel surface increases the small vortexes and the friction at the hot side, also contributing to an increased heat transfer. Instead of the ribbed surface of figures 2-4, the surface may be provided with grooves in the channel wall. The topology should be rather smooth at

the hot side of the channel where the service life limiting location is, to reduce the stress concentrations.

5        Figures 5 and 6 show a second embodiment of the invention, where the flow guiding surfaces are provided in the channel by means of a separate insert structure 16 having a central core, or body, with external thread portions 17. The structure 16 is adapted to be firmly fixed in the channel. The insert structure 16 is therefor provided with  
10       means 24 for holding distance between the channel wall 14 and the central core. Said distance holding means are here formed by radially projecting portions arranged at mutual distances in the longitudinal direction of the channel. As there are no thread portions 17 at the inner side of the  
15       channel wall 18, the insert does not block the coolant from access to the hot wall.

      Figures 7 and 8 show a third embodiment of the invention. As an alternative to the insert 16 shown in figures 5 and  
20       6, the insert is in this embodiment formed by a helical spiral 19 without a central core. The helical spiral 19, or spring, extends along the shape of an imaginary circular cylinder and is arranged in contact with at least a part of the inner channel wall.

25       The channels 11 may have a smaller cross section at the inlet manifold 12 than at the outlet manifold 13. Further, the width of a channel element in the circumferential direction of the rocket engine member may vary along the  
30       length of the channel element. Preferably, the width of the channel elements are chosen so that the channel elements are arranged in contact with each other, ie with no mutual spacings, in the circumferential direction in a



combustion chamber portion of the rocket engine member. On the other hand, the channel elements may have such width and be arranged in such a way that mutual spacings exist in the circumferential direction in a gas expansion portion of the rocket engine member. Preferably, separate cooling channel elements are stamped to present the desired ribbed or grooved surface structure. These elements are folded to the desired tapering channel width. Finally the separate channels are mounted into the rotational symmetric chamber and brazed. Thus, the manufacture of jacket and manifolds is simplified.

The method for manufacturing the rocket engine member is described below with reference to figures 9 and 10 according to one example. In figure 9, a sheet metal is shown in the form of a plate 20. One side of the plate is machined in such a way that the surface shows ribs and/or grooves. In figure 9, the sheet metal 20 is rolled by means of rotating and pressing a cylinder 21 against the plate. In this case, the cylinder is provided with helical ribs 22 on its outer surface. By said rolling process, the helical ribs 22 form diagonal grooves 23 in the sheet metal 20. Thereafter, the sheet is folded, or shaped, in such a way that it forms a part of a cooling channel, see figure 10. A plurality of such folded sheets are thereafter connected to a wall 14.

As an alternative, the surface structure may be applied to channels with parallel sides. This could be done by removal of material, e.g. by means of electro discharge machining.

The invention is not limited to the above-described embodiments, but several modifications are possible within the scope of the following claims. For example, the improved cold wall structure may also be applied to external expansion rocket engines like round and linear aero-spike engines. The flow guiding surface do not have to extend along the entire length of the cooling channel. Thus, the flow guiding surface can be applied to a part of the cooling channel subjected to the highest thermal load, e.g. the throat region. Further, the angle of the flow guiding surface in relation to the cooling channel axis may change along the length of the cooling channel. As an example, the angle is reduced from the inlet end of the channel to the outlet end of the channel.

The cooling channel may have a cross section shape which differs from U-shape, such as a circular or rectangular cross section shape.

The invention is not limited to the embodiments shown, where a plurality of cooling channels are attached to a continuous metal sheet in order to form a wall structure. Instead, the cooling channels may be attached sideways to each other, forming a load bearing wall structure on their own. The connection of the walls of the cooling channels to each other can be performed by welding.

Further, the flow guiding surface may be applied to the sheet metal surface in other ways than by rolling, such as by stamping.

Further, the distance holding means on the central core of the embodiment shown in Fig. 5 may instead be formed by said external thread portions.

- 5 Further, the rocket engine member may substantially only form the combustion chamber, substantially only form a nozzle for expansion of the hot gases, or form an element which is intended for both these functions.

## CLAIMS

1. A liquid fuel rocket engine member (10) having a  
5 load bearing wall structure (11, 14) comprising a  
plurality of cooling channels (11) for handling a coolant  
flow,  
c h a r a c t e r i z e d i n  
that each cooling channel (11) is provided with a flow  
10 guiding surface (15,16,17,19) extending at an angle to the  
cooling channel axis, for providing the axial coolant flow  
with an added radial directional flow component.
2. A member according to claim 1,  
15 c h a r a c t e r i z e d i n  
that the flow guiding surface (15) is incorporated into  
the channel wall (18).
3. A member according to claim 2,  
20 c h a r a c t e r i z e d i n  
that the flow guiding surface comprises a plurality of  
grooves in the channel wall (18).
4. A member according to claim 2 or 3,  
25 c h a r a c t e r i z e d i n  
that the flow guiding surface (15) comprises a plurality  
of ribs protruding (15) from the channel wall (18).
5. A member according to any one of claims 1-4,  
30 c h a r a c t e r i z e d i n  
that the flow guiding surface (16,17,19) comprises a  
separate structure inside the cooling channel (11).

6. A member according to claim 5,  
characterized in  
that the structure comprises a helical spiral (19).

5 7. A member according to claim 5,  
characterized in  
that the structure comprises a threaded screw (16, 17).

8. A member according to any one of claims 1-7,  
10 characterized in  
that the load bearing wall structure (11,14) comprises a  
curved wall (14), and that a wall of each of said cooling  
channels is attached to said curved wall.

15 9. A method for manufacturing a liquid fuel rocket  
engine member (10) having a load bearing wall structure  
(11, 14) comprising a plurality of cooling channels (11)  
for handling a coolant flow,  
characterized in the steps of  
20 shaping a sheet metal surface to provide a flow  
guiding surface (15),  
folding the sheet metal into cooling channels (11),  
and  
forming said wall structure by at least said folded  
25 sheet metals.

~~10. A method according to claim 9,  
characterized in the step of attaching said  
folded sheet metals to a wall (14), and thereby forming  
30 said wall structure.~~

11. A method according to claim 9 or 10,

c h a r a c t e r i z e d in that the sheet metal surface is shaped by stamping grooves into the surface.

- 5      12.    A method according to claim 9,10 or 11,  
c h a r a c t e r i z e d in  
that the sheet metal surface is shaped by stamping to form protruding ribs (15) on the surface.

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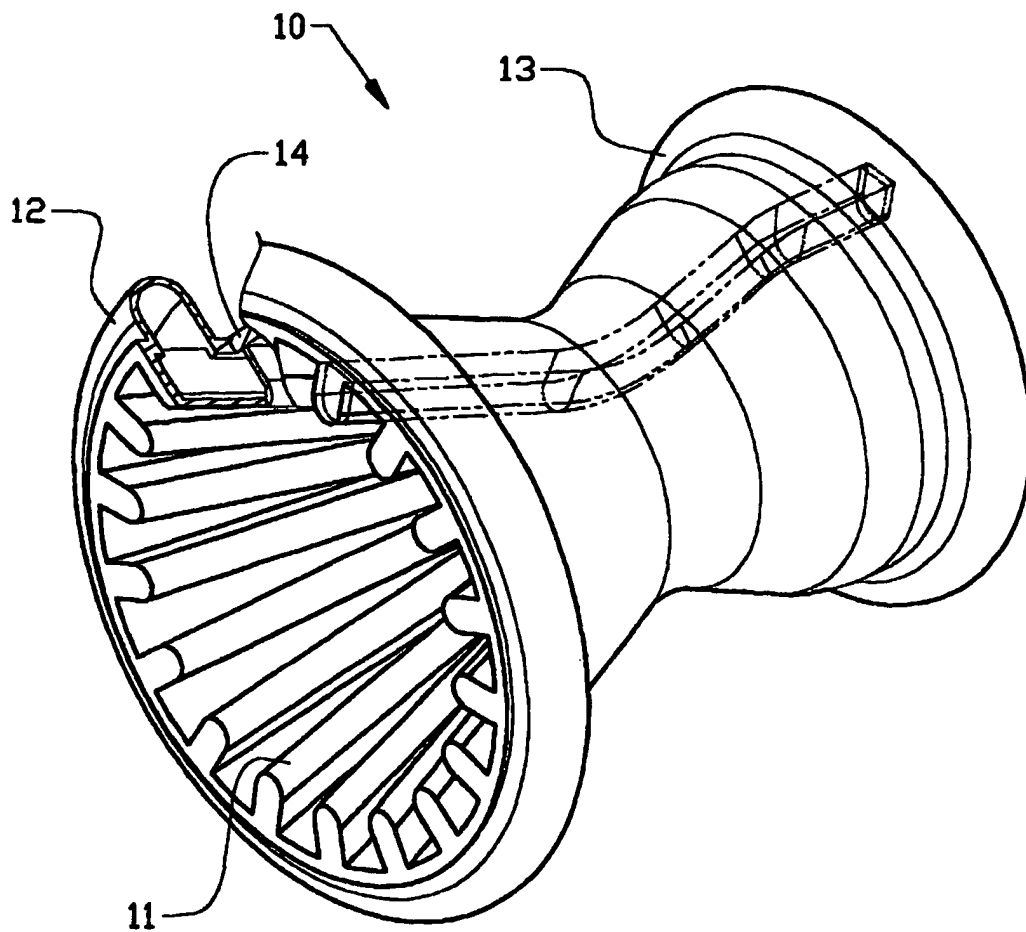


Fig.1

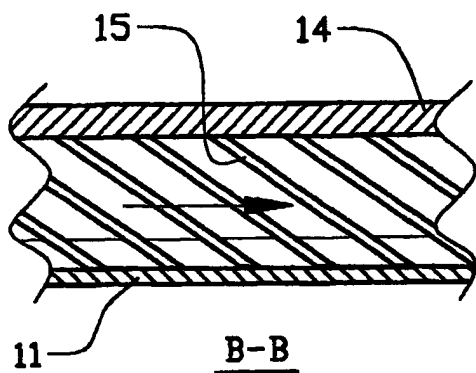


Fig.2

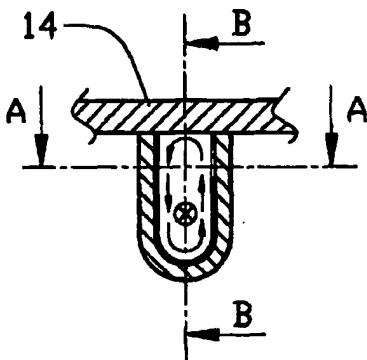
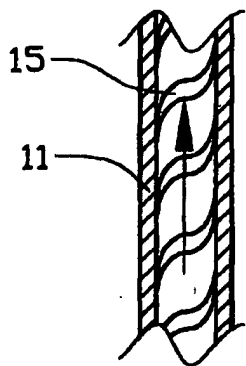


Fig.3



A-A Fig.4

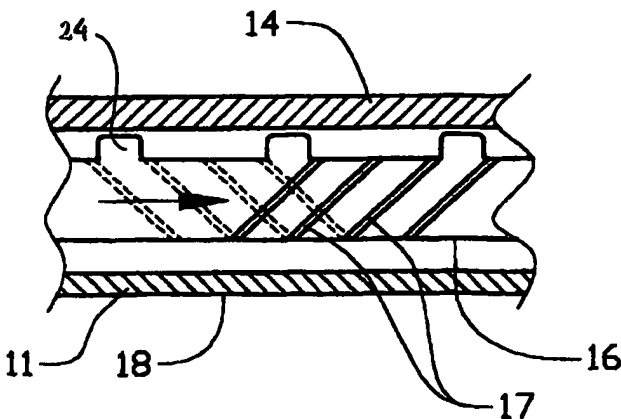


Fig.5

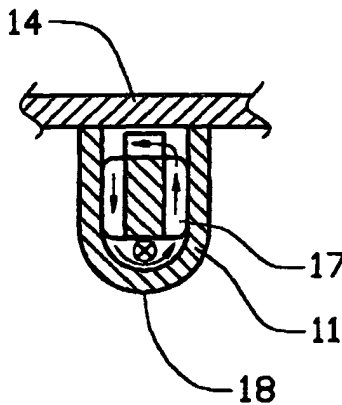


Fig.6



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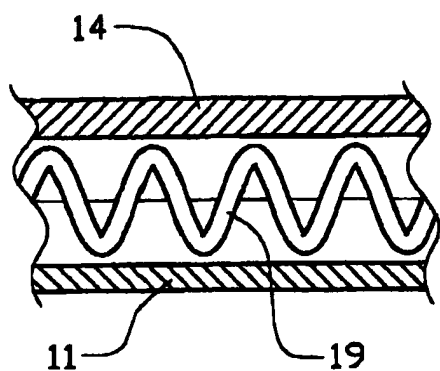


Fig. 7

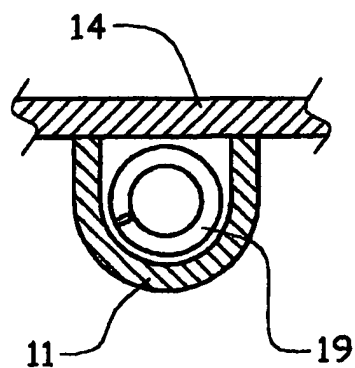


Fig. 8

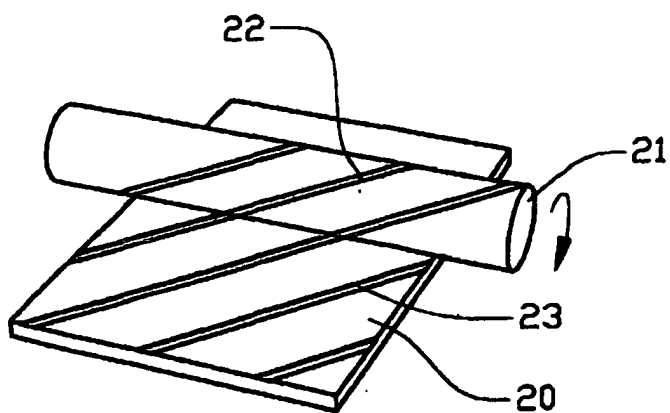


Fig. 9

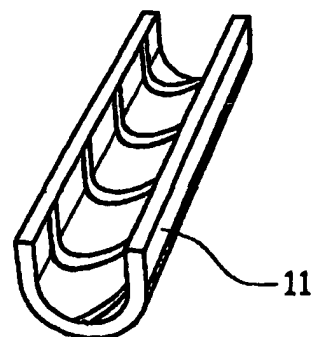


Fig. 10

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 02/00027

## A. CLASSIFICATION OF SUBJECT MATTER

IPC7: F02K 9/64, F02K 9/97

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: F02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0530721 A1 (RYHRGAS AKTIENGESSELLSCHAFT), 10 March 1993 (10.03.93)	1,9
Y	--	2-5
X	Derwent's abstract, No 97- 98746/09, week 9709, ABSTRACT OF SU, 2061890 (GERMES RES INST), 10 June 1996 (10.06.96)	1
Y	--	2-5
A	GB 904887 A (BRISTOL SIDDELEY ENGINES LIMITED), 5 Sept 1962 (05.09.62)	1-12
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☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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Date of the actual completion of the international search

18 March 2002

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**INTERNATIONAL SEARCH REPORT**

Information on patent family members

28/01/02

International application No.

PCT/SE 02/00027

Patent document cited in search report			Publication date	Patent family member(s)	Publication date
EP	0530721	A1	10/03/93	DE 4129598 A DE 59206604 D	11/03/93 00/00/00
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